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A NEW GENERATION OF PRODUCTS FOR THE ACCESS NETWORK

A TOTAL FIBRE MANAGEMENT SOLUTION

British Telecom (BT) has many years experience in Fibre Optic Transmission Systems and Infrastructures. This experience, when applied to the Access part of the network, resulted in the formation of a new set of fibre infrastructure requirements. This is BT's Optical Telecommunications Infrastructure for the Access Network, OTIAN [6, 7]. Invited by BT, Raychem has designed and developed a Fibre Infrastructure System Technology (FIST) to meet all Fibre Access Network requirements.

This report investigates the optical performance of this range of plant under two criteria:
Firstly, the evaluation and measurement of infrastructure loss mechanisms, and secondly, the assessment of the Raychem FIST product as a fibre delivery system with respect to the BT OTIAN criteria (philosophies).

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The OTIAN philosophy calls for a 'Total Fibre Management Solution' which:
- can create a stable optical platform
- provides network flexibility
- is future-proof
- is an end-to-end solution
- improves the quality of service
- integrates with existing infrastructure
- is cost-efficient

Infrastructure fibre loss mechanisms

There are a variety of well-documented optical fibre loss mechanisms [4, 5]. This paper, however, studies losses induced by particular network *operations* or *events.* These infrastructure fibre loss mechanisms are almost entirely due to macro- and micro-bending effects. This paper examines the hypothesis that :
- optical fibre in the Access Network is subject to a high level of handling
- losses will occur in fibres associated with the handling operation
- the losses induced are static and/or transient in nature
- there is a significant probability that the losses are system-affecting
- the above loss mechanism can be reduced to a non-service-affecting level by careful design of infrastructure plant elements

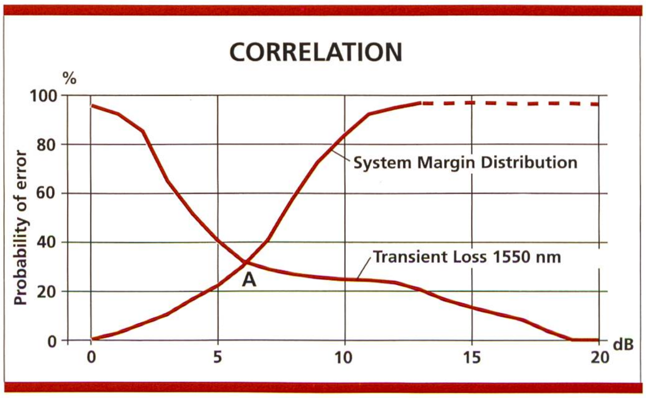


Fig. 1.
Correlation of the probability of a system-effecting error for a given system margin distribution. For example, point A shows that for a system with a system margin of £ 6 db, there is a probability ≥ 30 % that there will be errors due to transient effects.

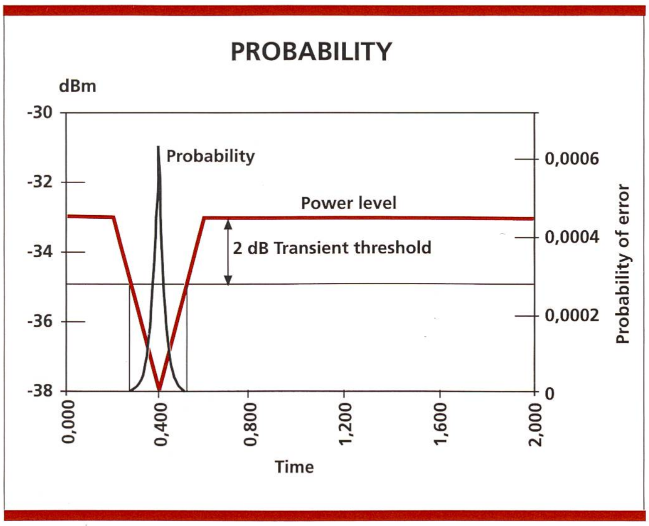


Fig. 2. Probability of error for a given system and transient.

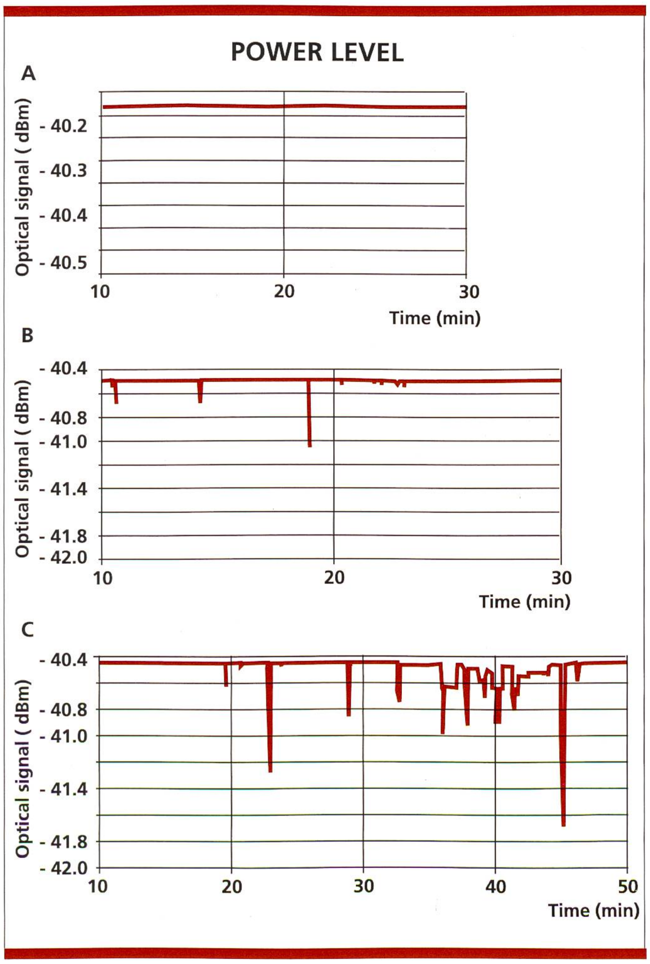


Fig. 3. Optical power level for organiser A, B, C.

BT investigation

Previous investigations [3] have outlined an 'induced' infrastructure loss known as 'transient loss'. This loss is associated with fibre handling and other network operations.

In order to try and quantify the cause-and-effect relationship between these losses and system performance, a laboratory experiment was conducted. A series of handling operations were carried out over a 1550-nm transmission system operating at 140 Mbits with a return-to-zero code. The results showed significant fibre losses and highlighted the importance of system margin in determining the error effect on a system. By examining the occurrence of system errors, the probability of a system-affecting loss occurring was quantified. Comparing this probability as a function of system margin, with estimates of current and future system margin profiles, one can approximate the likely effect on an optical system.

Figure 1 illustrates this relationship. One can see that there is a significant probability that an access network system of this type will be effected by transient loss.

This investigation was confined to one particular system configuration. The effect and results cannot be readily applied to all systems due to the complex relationship between several key parameters such as:

- **receiver characteristics**
  AGC response
  noise
  line code
- **system characteristics**
  system margin
  bit rate
- **static characteristics**
  loss
  reflections
  wavelength
- **dynamic characteristics**
  (induced transient loss)
  magnitude of loss
  duration
  rate of change

One can, however, derive a more general approximation by utilizing the static relationship between the signal-to-noise ratio and the probability of error for a binary signal [1] (1).

$$P(e) = \tfrac{1}{2}\,\mathrm{erfc}\,\frac{(S/N)^{\frac{1}{2}}}{2\sqrt{2}} \quad (1)$$

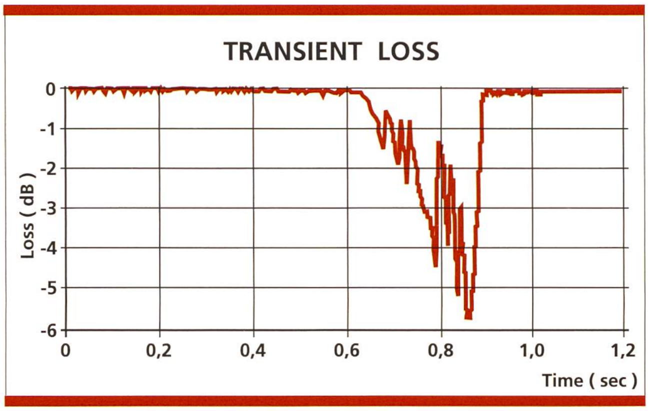


Fig. 4.
Highest measured transient loss. During normal operations organizers with multiple fibres on organizer trays (B, C) exhibited a high level of transients, whilst the organizer with single-circuit management (A) showed practically no losses. Another key factor was found to be the degree of fibre management both onto and from the organizer trays.

Applying this relationship to a theoretical system for a given transient yields a probability of error profile. One such condition can be represented by a 'hat' transient.
Figure 2 shows both the effect on received power and the corresponding estimated probability of error. Note that the probability only arises after a threshold of approximately 2 db is reached. Practical tests carried out over the BT optical reference test network recorded results well in excess of this value and concluded that the 'transient loss' phenomenon was a highly significant factor in assessing the performance of an optical fibre infrastructure.

Raychem investigation

BT OTIAN requirements have been generated to address all the issues associated with deploying optical fibre in the Access Network. OTIAN sets out to remove or reduce optical loss mechanism to a non-system-affecting level. Raychem has designed and developed the FIST range of products to meet these requirements.
In order to establish the optical performance of these products, a laboratory experiment was conducted. The FIST product (organizer A) and a selection of conventional fibre organizer (B and C) trays were placed under test. The optical power (at 1550 nm) was continuously monitored, whilst the organizer trays underwent typical handling operations.
Figure 3 shows the typical resultant data for each organizer type (A, B, C). A series of significant optical losses was noted, each loss being associated with a particular organizer operation. Organizer C has the highest number of loss events, while organizer A typically showed none. As well as the frequency of such events, the magnitude is also a critical factor. *Figure 4* shows the highest transient loss measured. This was seen on organizer C and has a value of 5.6 db. This is well in excess of the BT threshold value of 2 db. The maximum loss recorded for the FIST product (A) was 0.5 db.

Figure 5 compares the maximum recorded loss for each organizer. The maximum loss was found to occur when a non-active fibre was reaccessed. This is considered to be a common requirement in the Access Network. It was observed that the variation in optical performance amongst the organizers was due solely to the degree of fibre management incorporated into the plant design.

Comparative analysis

Testing carried out by BT showed transient loss on the FIST product not exceeding 0.7 db. Testing was carried out in field conditions as well as laboratory conditions. This value compares with the Raychem measurement of maximum loss, which was 0.5 db. The correlation is sufficient to give a high degree of confidence in both sets of independent data.

Optical fibre delivery system

The minimization or elimination of loss due to fibre handling is only one of many of the BT OTIAN requirements. These requirements outline the performance for a complete multi-functional fibre delivery system. In order to assess the Raychem FIST products against this criteria, it is appropriate to examine how the plant addresses the OTIAN philosophies.

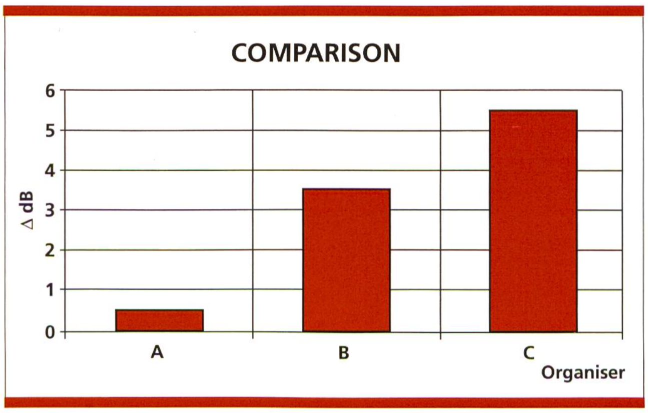


Fig. 5. Comparison between the highest transient for each organizer type.

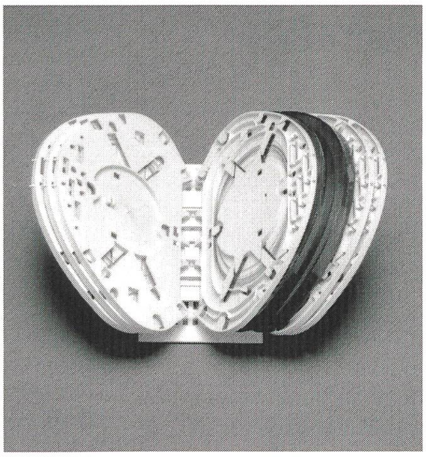


Fig. 6. FIST single-circuit subassembly.

Stable optical platform

Stability in the network is derived from the avoidance of service-affecting events. This philosophy calls for a total fibre management solution in infrastructure plant design. Stability must be maintained so that there is no effect on customer service even when the network is re-entered and fibres are accessed.

FIST products address this requirement by managing fibre on a single-circuit, subassembly basis. This means that for the part of the network where reaccess is required, customer-specific fibres are managed separately on a series of fibre splice trays. These trays then form subassemblies as illustrated in *Figure 6.* In addition, all fibres routed to and from the trays are completely managed. As identified earlier in this paper, this design approach greatly reduces the probability of a service-affecting fault due to network intervention.

Network flexibility

The infrastructure deployed must, by design, have the ability to be configured in many ways so that the best fit can be made between the infrastructure and the variable Access Network topology.

To address this, a modular approach to plant design has been applied. This has resulted in a small family of subassemblies, which can be configured together to generate many infrastructure architectures *(Fig. 6 and 7).* The facility to create cable loops within FIST joints provides complete flexibility in the allocation of fibre to a given area.

Future proof

The infrastructure must not prohibit the deployment of any future fibre-based technology. It must cater for point-to-point and point-to-multipoint systems. The selection and management of fibre and components should not prohibit the exploitation of any optical window. The infrastructure should cater for the variations in network fibre demand.

The FIST solution can be used for both point-to-point and point-to-multipoint networks. By designing a total fibre management solution and by tight control of all fibre components (e.g. optical splitters), the exploitation of any optical window is not compromized by the infrastructure elements or by fibre re-access.

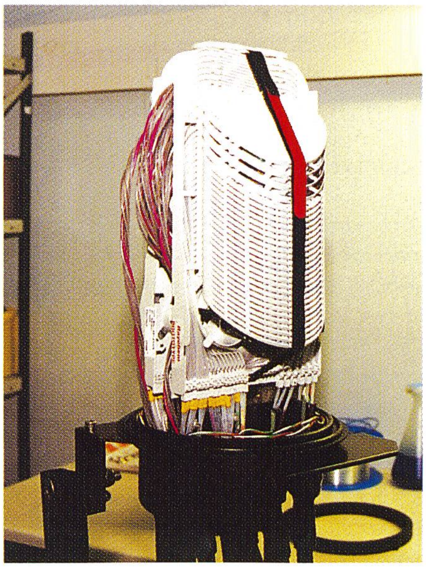


Fig. 7. FIST generic joint.

End-to-end solution

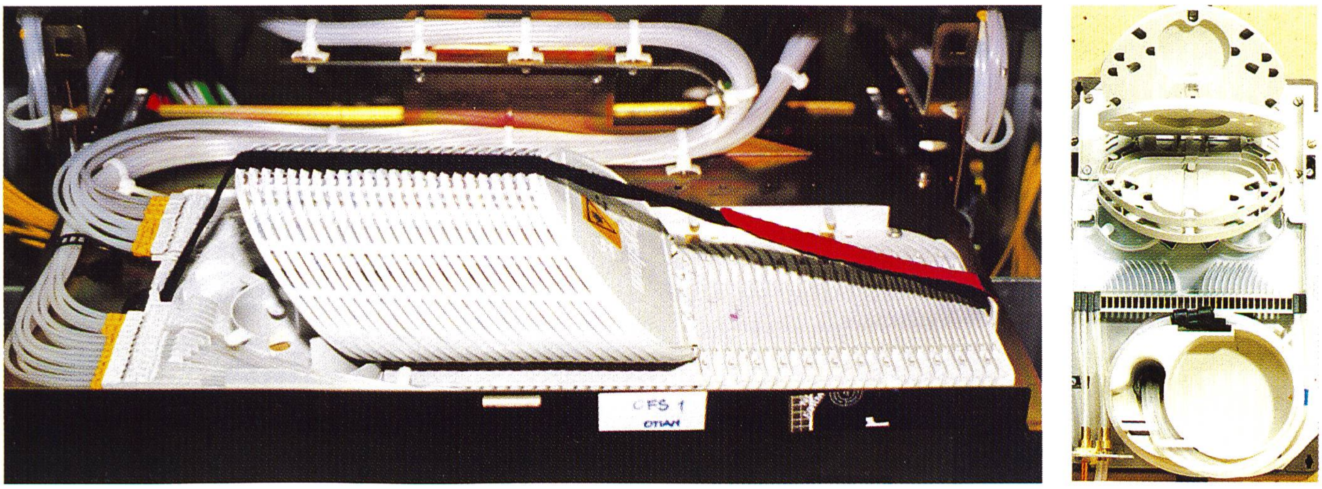
Optical performance is best measured and stability maintained if a single solution is used from the point of optical transmission to the point of reception.

There are also perceived cost and training-installation benefits associated with this philosophy.

FIST is a complete end-to-end optical fibre access network solution. It has a range of products for the Exchange, External Network and Customer premises.

Network reliability, stability, efficiency

Fig. 8. FIST shelf and box units.



and cost can now be measured, controlled and associated with a particular company or OTIAN solution.

Improved quality of service

The infrastructure should increase network reliability and performance, whilst decreasing customer provision times, down time, disruption and cost.
The FIST solution allows networks to be built in a ring structure. This provides route diversity, which greatly increases the quality of service.
The BT- and Raychem-shared understanding and research into component reliability ensures effective quality controls on all key fibre components. The FIST solution ensures network stability, which increases network performance.

Integration with existing infrastructure

Existing infrastructure represents considerable investment. The development of any new infrastructure item should exploit to the full all existing infrastructure build that falls within the functionality and performance criteria of the new infrastructure build.
The modular design of FIST makes it adaptable to existing infrastructure elements such as rack, joint, cabinate and box types. The fibre management and dimensioning of the joints are adaptable to a variety of civil structures and cable types.

Cost efficiency

Through infrastructure design and installation practice, every avenue must be explored in order to make the network more cost-efficient.
The FIST solution exploits the design principles of modularity and commonality. This is a recognized method for cost reduction. It also has the potential to reduce operator cost in the areas of :
- reduced installation times
- reduced training overhead

The cable-loop facility allows for the cost-effective distribution of optical fibre throughout the network. This facility avoids the over-provision of network capacity and hence can reduce the overall cost per line.

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ZUSAMMENFASSUNG

Eine neue Generation von Produkten für das Anschlussnetz

British Telecom (BT) hat jahrelange Erfahrung mit optischen Übertragungssystemen (Glasfaser) und deren Infrastrukturen. Als diese Erfahrungen beim Anschlussteil des Netzwerkes angewandt wurden, resultierte daraus die Bildung einer neuen Serie von Anforderungen für die Glasfaser-Infrastruktur. Dies sind optische Telekommunikations-Infrastrukturen für das Anschlussnetz. Auf Einladung von BT hat Raychem eine FIST-Technologie entwickelt, um allen Anforderungen des Glasfaser-Anschlussnetzes gerecht zu werden.

Conclusions

With reference to the investigation hypothesis, it is concluded that:
- optical fibre in the Access Network is subject to a high level of handling
- losses will occur in fibres associated with handling operations
- the losses induced are predominately transient in nature
- there is sufficient test data to establish that these losses are system-affecting and to establish that the probability of occurrence is significant
- the above loss mechanism can be reduced to a non-service-affecting level by the careful design of infrastructure plant elements, e.g. a Raychem FIST product and other OTIAN compliant products
- the Raychem's FIST product was shown to greatly reduce the transient loss mechanism. The product was seen to prevent transients from occurring and to reduce losses to below the service-affecting level.
- the Raychem FIST product has a high optical performance, meeting all the BT OTIAN criteria, and can therefore be considered a high-performance Access Network fibre delivery system 9.1

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